DESIGN OF STEAM TURBO-GENERATOR STATION

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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Design of a 20,000 k.w.
steam turbo-generator

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Design of a 20000 K. W.
Steam Turbo-Generator Station

A THESIS

PRESENTED BY

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PART I

INTRODUCTION AND STATEMENT OF PROBLEM

Part I

INTRODUCTION AND STATEMENT OF PROBLEM.

The following thesis is a consideration of the mechanical and electrical features involved in the design of a large, modern, central station. The work is not intended to be general for a specific case has been assumed. Further, the time and scope of the work does not permit of original designs of apparatus, nor would it be advisable to do so; but, rather, directs the attention toward analyzing possible existing conditions, deciding upon best arrangements, etc. to secure prompt and reliable execution of the requirements, and then selecting the proper apparatus from the numerous standard makes on the market.

It is proposed to design a central station, the maximum demand on which shall be not greater than 20,000 K.W., the load to be both power and lighting. Of the power load, 10,000 K.W. is to be transmitted 40 miles and the rest is the local load. In connection with the lighting load, a 650 K.W. arc light sub-station is to be designed. In connection with the transmission line, one, of

a system of typical rotary converter substations will be investigated. The output of the generating station is given graphically in the form of an average load curve.

The design assumes good railroad facilities and the location of the plant to be near a river, or some other source of permanent water supply and accordingly no effort has been made to cool and re-use any circulation or discharge water. Great care,however, was taken in determining the probable city datum line when arranging foundations and basements. It is quite probable, since no definite locality is taken for the plant, that the conditions assumed are more or less ideal and many obstacles, peculiar to individual plants, are avoided.

Considerable time was devoted to studying existing conditions and arrangements in such modern stations as the Fisk and Quary Street Stations of the Commonwealth Edison Co., Chicago, the Southern Wisconsin Power Co!s

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plant at Kilbourn, Wis., and the Western Avenue Station of the Chicago City Railways Co.

PART II

BUILDINGS.

The main building is a fireproof structure of red pressed brick and steel on a concrete foundation. Concrete is used throughout in the construction of roof coverings and floors. The building is divided lengthwise into three rooms:

(a) Turbine Room.

The turbine room is 80 ft. x 224 ft. inside dimensions, the height from floor line to lower member of roof structure being 60 ft. A basement 9 ft. high provides room for the major portion of the piping and for conduits. On the boiler room side is located a 7 ft. visitor's gallery,extending the entire length of the building. The space on the opposite side of the turbines is almost entirely devoted to an enclosed apartment on the main floor for transformers, etc., and above this is the switchboard gallery. At one end, a railroad track enters the building through a door amply large enough to admit a loaded car. This permits of the unloading of heavy machinery by the use of a crane. Suitable space for offices is found on the main floor and galleries.

(b) Boiler Room.

The principal dimensions of this room are:

Length	inside	188 ft.
Width	"	111 ft.

Height from floor line to lower chord of roof structure 51 ft.

Depth of roof girders 14 ft.;the boiler room basement is 14 ft. high and is divided into apartments containing the piping for each section of boilers. In this basement are located also, the intake tunnels and wells, which supply water for condensers, fire line, and house service. The basement floor line of the boiler room is 3 1/2 ft. below that of the turbine room basement.

(c) Coal House.

The coal house is a room 188 ft. long and 23 ft. wide. It contains the necessary track hoppers and ash bunkers for the system of coal and ash handling to be described later. A railroad track extends the entire length of

the room.

The entire plant is well lightedby large double windows and skylights. A 5 ton hand-power crane is provided for each firing room. A 50 ton electric crane, with a 5 ton auxiliary hoist, spans the width of the turbine room over the turbines and gallaries. An electric coal handling crane is installed in the coal house.

PART III

COAL AND ASH HANDLING.

In a station of this size, the proposed elaborate system of conveyors is warranted, as the expense of coal and ash handling will probably be the largest item of the operating charges. Storage of fuel is an importand consideration in the question of continuity of service. To take care of this feature, a storage yard is to be located on a spur of track leading from the main coal house track.

The coal bunkers are made of steel and concrete and are placed above the boilers. Separate bunkers are made for each boiler so as to reduce the spreading of a fire once started in a bunker. Ash bunkers and ash receiving hoppers are made of concrete as the corrosive action of ashes quickly destroys thesteel.

Each battery of six boilers has a conveyor system complete in itself. Coal is brought into the coal house on the railroad in the usual

coal cars and either dumped to the track hoppers or unloaded by the coal handling crane. From here it is taken up by the conveyor and discharged into the overhead bunkers. A crusher placed between the track hopper and main conveyor is used when lump coal is supplied. The same system takes care of the ashes, which are taken from the receiving hoppers underneath the stokers and discharged into an overhead ash bunker in the coal house. This bunker is emptied into the car below by means of a valve and spout. The fine coal, falling through the grate, is collected in a fine coal hopper in front of the ash hopper and discharged into the conveyor system. The stoker magazines are fed from the overhead bunkers through a flexible spout. Two motors are required for each individual system, one a 12 H.P. induction motor geared to the conveyor driver, the other a 5 H.P. induction motor is belted to the crusher. The coal bunkers are of suffi-

cient capacity so that once full, a storage for several days run is assured.

PART IV

BOILERS.

The general arrangement of the boiler plant is in four batteries of six Babcock and Wilcox boilers, placed back to back. Each boiler is rated at 508 H.P., has 5000 sq. ft. of heating surface, 8 ft. x 10 ft. Babcock and Wilcox chain grates, and provided with a superheater of approximately 1000 sq. ft. of heating surface. The foundations for the boilers are those recommended by the B. & W. Co. The station pressure is 180 lbs. per sq. in. and the equipment is to operate with 150° F. superheat. The chain grates are driven by 3 H.P., vertical steam engines, one engine being installed, for each section of two boilers. The engines are suitably mounted on the side of the boiler setting. It is necessary to have only two engines in use at a time unless the line shaft is sectionalized.

The smoke connections from the boilers are 8 ft. x 3 ft. and are taken from the rear of the settings, which are placed 10 ft. between backs to allow ample room for bends.

These connections enter a flue overhead, which leads directly to the stack. A damper is placed in each connection.

PART V

CHIMNEYS.

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The plant has two, circular, steel plate stacks, one for each section of twelve boilers. These are supported on steel structures above the boiler setting, which is a very good arrangement and has the advantage of saving space and avoids the use of extensive breeching. Each stack is 200 ft. in height above the grate surface, is 16 ft. internal diameter at the top, and the plates used in the construction are 1/2 in. thick at the bottom and 1/4 in. at the top. A fire brick lining, 11 in. to 4 1/2 in. thick is built up in the interior of each stack. The stacks are centrally located as regards each section of twelve boilers and two flues, 37 ft. long and of 80 sq. ft. average cross-section, enter on opposite sides. While it is possible with this arrangement to use economizers, it was not deemed necessary nor advisable to install them. The estimated probable temperature of flue gas varies from 500° F. to 680° F. There are two cleaning doors, 3 ft. x 2 ft. near the base of each stack and galvanized iron roof aprons are provided.

PART VI

TURBINES

The many practical advantages of steam turbines over large reciprocating engines and the successful operation of modern steam turbo-generator stations, seemed a sufficient reason to warrant the selection of Steam turbines as prime movers without further investigating the practibility of using recipbocating engines. The choice of size of units was based on a consideration of the average load curve which was plotted from data carefully collected from practice. Five, vertical, five stage, Curtis turbines, condenser base type, direct-connected to General Electric generators will be used. Four of these will be of 5000 K.W. capacity, normal speed of 750 R.P.M., and one 3000 K.W., 750 R.P.M., one of the larger units being considered in the nature of a reserve.

In the boiler room basement, a large, steam driven, plunger pump in connection with an accumulator and circulating pipes, maintains the oil pressure in the step bearings of the

turbines. As an auxiliary to each unit, a triplex steam pump is installed to be used in case of failure of the larger pump. The foundations of the turbines are built up from the basement floor and with turbines in place, the bottoms of the condensers are 6 in. above the turbine room floor. With a proper selection of units to have in operation at a given time, it will be seen by reference to the load curve that any machine need never be run below full-load conditions.

PART VII

BOILER AND TURBINE PIPING

The steam header for each section of six boilers is placed on roller supports in the basement near the rear of the boiler setting and extends the entire length of the section. Adjacent headers are cross-connected, loops being provided for expansion. This arrangement permits any turbine being supplied from any battery of boilers. The main header for each section is a 14in. pipe and the feeders from the boilers are 6 in. A check valve and a globe valve near the header connection are provided for each feeder. Each boiler is equipped with two 5 in. pop. valves and also a pipe permitting blowing off of steam above the roof.

The stroker engines are supplied with steam from an auxiniary pipe connection on top of the boiler and exhaust into a header leading to the atmosphere. There are three blow-off connections to each boiler two for the mud drum, and one for the superheater drain, which discharge into 5 in blow-off mains in the

basement. Each blow-off connection is provided witha blow-off cock and a globe valve. The mains for two sections are brought together at the turbine room end of the boiler room and from here a pipe leads into the discharge tunnel.

THE BOILER FEED: The boiler feed pumps are 16" x 10" x 24" Dean, vertical, double acting, single cylinder, pumps and two are installed in a pit alongside of each condenser in the turbine room. The piping scheme makes the system unusally flexible for a plant of this size. A Cochrane heater performs the functions of both hot well and heater as the condensed steam is pumped from the condenser into the heater. Feed water leaving the heater will be about 160° F., and is drawn in by suction from the heater and is pumped direct to a hot feed water main in the basement of the boiler room. The feed water pipes leading to the sections of boilers tap onto this main. A cold water suction is also arranged for, and the hot water system is duplicated by a cold water system. By proper manipulation of valves in the mains any section of boilers can be fed by any pump with either hot or cold water.

The pipe connection to the drums comes up from the hot main and a check valve and globe valve are fitted in it; also there is a shut-off valve right at the drum.

Each main steam header leads directly to a 5000 K.W. turbine, and has, just before its passing through the wall, a valve which can be operated from the turbine gallery and a connection for steam supply to condenser auxiliaries. A motor operated valve is placed at the turbine. It is not necessary to install a complete system of drips and drains as superheat is used and the main header has but one drain which is located in the boiler room basement and discharges into the blow-off main.

PART VIII

CONDENSERS AND AUXILIARIES.

The calculation of the condensing surface required is based upon a temperature in the steam side corresponding to the absolute pressure used. The temperature of the cooling water was taken to be 65° F. and it is desired to maintain a pressure of 2 in. absolute in the condenser. Worthington surface condensers are to be used, specially designad for Curtis steam turbine base. Assuming a stean consumption of 20 lbs. per K.W.H., as recommended by this company for the above stated condition, the installation of each 5000 K.W. unit requires the following apparatus:

(1.) Condenser, having 14000 sq. ft. cooling surface; 11000 gallons per minute of cooling water required.

(2.) A 20" left hand, single stage, Worthington volute centrifugal pump with a maximum capacity of 12000 gallons per minute, direct connected to a 9" x 12", 325 R.P.M. 113 H.P., Knowles single, vertical, high speed steam engine. Steam is supplied by a 3" pipe and the exhaust pipe is 4" in diameter.

(3.) A 10" x 22" x 18", single, steam driven, horizontal, straight line, Blake Rotative Dry Vacuum Pump, having a capacity of 790 cu. ft. per min., and making 100 r.p. M. The pump requires a 2" steam pipe, 3" exhaust, 8" suction, and a 6" discharge pipe. The use of Meyer cut-off valves on the steam cylinder is recommended.

(4.) A 4" single stage, vertical shaft, Worthington Volute Hotwell Pump for high head service. This pump has a maxium capacity of 450 gals. per min., makes 1800r.p.m., and is rated at 18 H.P. The pump is located in the basement and is direct connected to a 20 H.P. induction motor on the main floor.

(5.) A Cochrane Feed Water Heater, having approximately 2000 sq. ft. heating surface. The heater is of the baffle type and performs the functions of both hot well and heater. It receives the discharge from the hot well pump and is heated by the exhaust from the volute, and air pump engines, and the feed water pumps. The exhaust inlet is 8" and a 6" atmospheric relief is provided.

The 3000 K.W. unit is to have apparatus of the same make and kind with the following ratings:

(1). Condenser of 8500 sq. ft. cooling surface and requiring 6600 gals. per min. of circulation water.

(2). A 16" volute pump; maximum capacity of 7500 gals. per min. , direct connected to an 8" x 10", 350 r.p.m., 80 H.P. engine, The engine is supplied with steam by a 2 1/2" steam pipe and has a 3" exhause pipe.

(3). A 10" x 18" x 18" dry vacuum pump with a capacity of 530 cu. ft. per min., at 100 r.p.m. The pump requires a 2" steam pipe, a 3" exhaust, 8" suction, and a 5" discharge pipe.

(4). A 3" hot well pump, maximum capacity of 250 gals. per min., 11 1/2 H.P. and making 2000 r.p.m., direct connected to a 12 H.P. induction motor.

(5). A heater having 1400 sq. ft. of heating surface.

Steam is supplied at station pressure to the auxiliaries from a 5" auxiliary steam header. A Baum oil separator is placed in the 8" exhaust header just before it enters the heater. The condensers are provided with a 30" free air exhaust which together with the 6" exhaust from the air pumps lead through the boiler room roof. Oil to auxiliaries is supplied by a gravity system. Pipes run to all of the bearings from storage tanks placed near the roof of the station. After being used the oil flows through pipes to filters in the basement and is then pumped to the storage tanks for re-use.

ADDITIONAL AUXILIARIES: A 6" Underwriter Two Stage Turbine Pump built by the Worthington Co. , is located in the boiler room basement. This pump has a capacity of 1500 gals. per min. at a standard working pressure of 100 lbs. per sq. in. and is direct connected to a 220 H.P. induction motor. The fire line is so arranged that all coal bunkers are easily reached.

City water is depended upon for house service and transformer cooling. A 16" x 10" x 12" duplex pump supplies water for wetting coal and ashes and general flushing.

PART X.

ELECTRICAL FEATURES.

Location of Apparatus.

The electrical apparatus is located in an enclosed apartment and gallery on the opposite side of the turbine room from the boiler room. The enclosed apartment on the turbine floor contains the high and low tension buses, the power transformers for the transmission lines, the low tension switches for power and lighting circuits, and the induction regulators for the lighting circuits. In the basement, below the induction regulators is located the cable conduits through which the power and lighting circuits leave the building. The storage battery is also located in the basement. The covering of the enclosed apartment forms the switchboard gallery upon which is located the lightning arresters for the transmission lines, the switchboard, and the large oil switches for the generators, house transformers, bus tie, and transmission lines. The enclosed apartment is accessible by stairways from the gallery and doors from the turbine room floor. Stairways lead from main floor to the switchboard gallery.

GENERATORS: There are five General Electric Alternators, one 3000 K.W. and four 5000 K.W. 4 pole- 25 cycle- operating at 750 r.p.m. All machines are of the revolving field type, air cooled, armatures Y connected, generate at 2300 volts to neutral, and are direct connected to Curtis vertical turbines.

SWITCHING METHODS: The output of the turbo-alternators passes through selector oil switches to one of two sets of 2300 volt bus bars which permits the units to be operated on the same or separate buses. The two sets of 2300 volt bus bars supply the transmission lines, local power circuits, and the lighting circuits. Two banks of three 1888 K.V.A., 2300-33000- volt transformers are connected with each set of 2300 volt bus bars through disconnects and oil switches. The high tension side is connected to the 33000 volt bus through oil and connecting switches. There is a single 33000 volt bus with provision for future duplication. Two 33000 volt transmission lines

are taken out of the station and each is provided with disconnects and oil switches. The four power circuits are connected to the 2300 volt buses through connecting and oil switches. The ten lighting circuits are each 3 phase 4 wire and are so arranged that they may be thrown to either low tension bus by means of connecting and oil switches. The line side of each phase switch is connected to a single phase induction regulator provided with pot-heads on both sides.

BUSES:

(1) Direct Current Buses.

The D.C. buses consist of a common positive bus, a negative main, and an auxiliary negative bus of copper bars. The supports are marble brackets on the back of the switchboard.

(2). The 2300 Volt Buses.

The low tension buses are 3 phase 4 wire with grounded neutral. The buses are of insulated copper arranged one above the other, are 6 sq. in. cross-sectional area, and are held by brackets on the pipe supports. The buses are sectionalized by break-ups between each

generator and the neutral bus is permanently grounded.

(3) The 33,000 volt Buses.

There are three sets of high tension buses, two being the transformer buses and the other the main bus. The bus-bars which are supported by vertical porcelain insulators are of soft drawn solid copper wire 30,600-C.M. They are arranged one above the other in brick bus compartments with three inch concsete barriers. The sides of the bus compartments are cut away where leads are taken off to the disconnects. The disconnect compartments are arranged on one side of the buses and are closed by wooden doors. On one end of each of the two transformer buses, leads are taken off to the 3 phases of the transformers. On the other end of each of these buses, disconnects are taken off to one side of the bus oil-switch. The other side of the bus switch is connected to the central part of the main bus by means of disconnects. The main bus is sectionalized at the center by a set of "break-ups" thus insuring separation

of the bus for cleaning and repairs. At the end of the main bus, leads are taken off to the disconnects of the line switches.

The Transmission Line.

The transmission line is connected to the main 33,000 volt bus through oil and connecting switches. The line side of the line oil switches are connected to the 33,000 volt overhead transmission lines through current transformers located on the top of the main bus, the choke coils suspended from the ceiling of the enclosed apartment, and the line disconnects. The transmission lines leave the station through outlets, manufactured by the R.Thomas Co., located in the wall of the enclosed apartment. The leads after passing through the wall outlets connect to the line proper which leaves from the steel structure at the side of the building. The transmission lines are protected from lightning by Type G.E., Form 1 aluminum cell lightning arresters.

Power is transmitted to the terminal station a distance of 40 miles, over two separate lines running in parallel on the same right of way. Each of the lines is of sufficient capacity to safely carry the maximum load of 10,000 K.W. At the center of these lines will be located a switching station, equipped with oil switches and lightning arresters. With this arrangement, a cross connection can be made and one-half of either line cut out while the remainder is in operation. This method of providing a switching station at the center of the line facilitates repairs and the location of trouble . The lines are carried on wooden poles, and are transposed every 3.5 miles. The insulators are of the pin type and are supported from the cross-arms by two inch pipe pins. Each pole is equipped with a grounded protective top 90 inches long. A 5/16" galvanized iron cable runs from pole to pole above the transmission lines.

Calculated Data on Transmission Line.

Length of line 40 miles.

Power to be transmitted -10,000 K.W.

Stranded aluminum conductor

.58" diameter

250,000- C.M.

Weight in lbs. per wire- 1215

Average temperature rise-- 75° F.

Resistance per mile at average temperature-.358 ohms

Distance between wires- 50 inches

Reactance per 1000 ft.-- .094 ohms

Total reactance of line- 19.853 ohms

Power factor- .85 (lagging)

Charging current 2 amps.

SWITCHES: There are three distinctive types of power switches employed in the station, viz:- motor, solenoid, and manually operated.

(1) Motor operated switches.

The Motor operated switches are all T.P. S.T. General Electric type H_3. The switches on the generators and low tension side of the 1888 K.V.A. transformers are interlocking so that the buses may not be tied by circuit switches.

The switches on the high tension side of the transmission line and the bus are also H_3 but are not interlocking.

(2) Solenoid Operated.

Solenoid operated Type F, form K_2, oil break switches are employed on the following circuits: the two banks of house transformers; the power feeders; the lighting feeders; and the are sub-station feeder. The S.P.S.T.-K_2 switches on the lighting circuit have their corresponding phases interlocking. Interlocking T.P.S.T.- K_2 switches are installed on the power circuits. The T.P.S.T.- K_2 switches on the two-banks of station transformers may be thrown to low tension bus #1 only, and the T.P.S.T.-K_2 switches on the arc bus may only be thrown to #2 low tension bus. It is seen from the switching arrangement described above that it is impossible to tie the two 2300 -volt buses except by means of the bus tie switch, which has special synchroscope connections for this purpose.

The generator field switches are 250-volt 500- amp. solenoid operated.

The principle disconnecting switches are rated below:

Circuit	No.of Blades	Amp. Capacity.
5,000 K.W. Generator	6	1250
3,000 K.W. Generator	4	750
2300-volt Bus tie	6	5000
2300-volt Bus section	6	5000
33000-volt " switch	1	200
3300 volt sectionalizing switch	1	200

Disconnects not listed above are single pole.

THE SWITCHBOARD: The remote control switchboard consists of fourteen fanels and a swinging panel of gray Vermont marble. From left to right, the panels are:- 1 Swinging Syrchroscope panel; five generator panels; 1 special panel for tirrill, exciters, storage battery and house lights; 1 transmission line panel; 1 special panel for other tirrill, bus tie, arc bus, and house transformers; 1 power circuit panel; and 5 lighting circuit panels.

GENERATOR SPECIFICATIONS..

The equipment for each of the four 5,000 K.W. generators is as follows:

1. Horizontal edgewise D.C. Ammeter, 5 amp. capacity, and 500 amp scale.

1- 500 amp. Weston switchboard shunt.

3- Horizontal edgewise ammeters, 2,000 amp. scale

3- Horizontal edgewise indicating wattmeters 8,000 K.W. scale

1- Horizontal edgewise power factor indicator, 110 volts, 60-100-60 per cent.

1- Horizontal edgewise, 2700- volt scale and 110- volt winding.

1- Thompson polyphase recording wattmeter, 5 emp., 110 volts.

3- 3 point overload relays with 5 amp. windings.

5- D. T. S. T. 25- amp., 125 volt lever switches, two for main generator H_3 oil switches, one for turbine governor, one for electrically operated field switch, and one for field rheostat.

1- S. T. S. T. 25- amp., 125- volt lewer switch for opening D. C. control to relays.

1- Six point synchronizing recptacle.

1- Nine-point , voltmeter switch for obtaining generator and bus volts.

1- Solenoid operated field switchb with discharge clips and resistance.

1- S.P.D.T.- selector switch for selecting negative main or auxiliary bus for field excitation.

3- 2000- amp. series trans, ratio 250:1 - 40 watt. for recording and indicating wattmeters, and power factor metors.

3- 2000 amp. series trans, ratio 250:1-40 watt. for ammeters and overload relays.

3- 2300 to 110-volt, 200- watt, ratio 200/1 shunt transformers for mach. volts, recording and indicating wattmeters and power factor meters. The shunt trans. are protected by fuses.

3- T.P.S.T. 1200 amp., 2300 volt form H_3 oil switches.

THE POWER TRANSFORMERS:

The banks of transformers between the low and high tension buses consist of three 1888-K.V.A. 2300- 33000- volt, water cooled, oil insulated General Electric trans formers connected delta to delta. They are protected by overload relays on the oil switches on the low tension side. Two banks of 300 K.W., self cooled, oil insulated transformers are installed for station auxilaries. They are connected Y to Y, and step down from 2300 to 440- volts for the large motors and 110- volts for the A.C. control. A. station lighting transformer of 10 K.W. capacity is connected on the primary side to the No. 1 low tension bus through expulsion fuses.

THE POWER AND LIGHTING FEEDERS:

The four power circuits are three phase four wire and are connected so that they may be closed to either set of low tension buses by means of 3 P.S.T. interlocking oil switches. The lighting feeders are also three

phase four wire and are connected so that each phase may be thrown to either set of buses. Each phase wire after passing through the switch is connected to a 16.5 K.W. Type I.R.S. single phase induction regulator with pot heads on both sides.

CONTROL OF APPARATUS:

The control of the apparatus is accomplished by both alternating and direct current.

A. A.C. Control:

The A. C. control bus fed from the bank of station transformers is three phase, three wire and is located on the back of the switchboard. Leads are taken from this bus through the hand controlled reversing switch and limit switch to the three phase motor mounted on the frame of the single phase induction regulators.

B. Direct Current Control.

D. C. is employed to control the series motors on the turbine governors and to control all the electrically operated switches. The solenoids controlling the field rheostats are operated by D. C. and all switches provided

with overload relays are tripped out by D.C. when the relays close the circuit.

The D.C. for the control is normally supplied to the operating bus by the main negative and positive exciter buses, the emergency control supply being the storage battery.

THE EXCITER SYSTEM:

The exciter system operates at 125-volts and consists of one 150 K.W. exciter direct connected to a horizontal Custis steam turbine, and three 100-K.W. exciters direct connected to three phase 440- volt induction motors.

The positive side of the exciters is connected to the common positive bus by means of a S.P.S.T. knife switch. The negative side may be connected to either the main or auxilary negative buses by means of the negative selector switches. The main and auxilary negative buses may be operated at different pressures or tied together by means of the selector switches on the generator panels. The exciters

are equalized on the negative side. The shunt field is controlled by main and equalizing rheostats connected in series. The use of the equalizing rheostat is necessary since tirrill regulators are being used with exciters of large capacity.

TIRRILL REGULATORS:

Two tirrill regulators type T.A.- Form 125 F_8 are installed in the station and are so connected that the two 2300- volt buses may be maintained at the same or different pressure. This arrangement makes it possible to have the local load on one bus at 2300- volts, and the other bus carrying the transmission line load at a pressure such that the terminal voltage will be maintained constant at 33,000- volts.

THE STORAGE BATTERY:

The storage battery consisting of sixty cells, Willard Type "E"$_5$, is divided into halves and is so connected that either or both halves may be charged while the entire battery may be arranged in series for discharge. The

battery is used only for emergency lighting and control during a shut down period.

STATION LIGHTING:

The station lights may be carried by either the house lighting transformer or the exciter bus bars. The board lights may be supplied from any one of three sources, via; the house lighting transformer, the exciter bus bars, or the storage battery. This arrangement possesses the advantage that it enables the operator to obtain light on the board under all conditions.

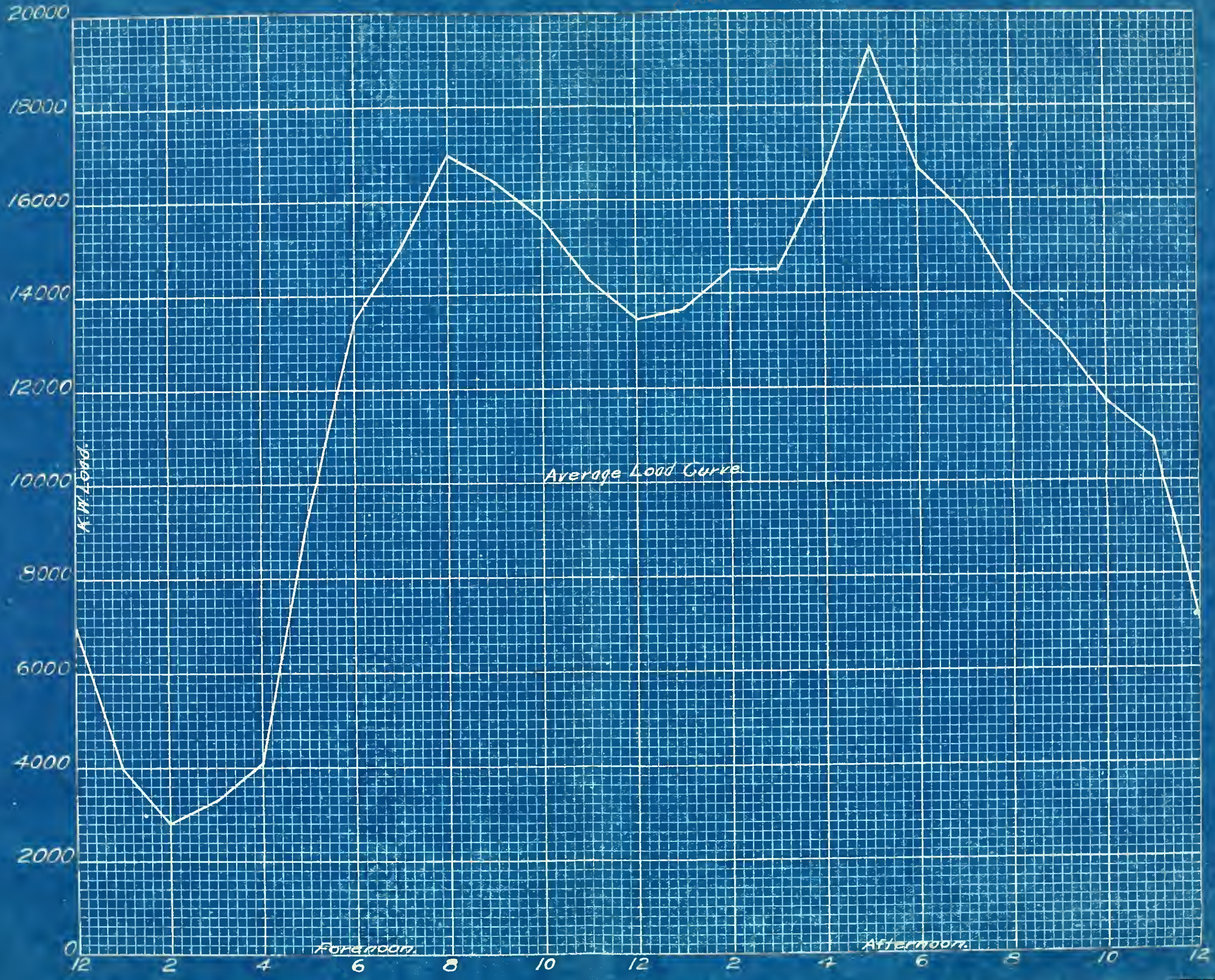
THE ARC LIGHT SUB-STATION:

The arc light sub-station has a capacity of 1500 arcs. The power is supplied to the sub-station at a potential of 2300- volts and is transformed to 4250- volts by means of three General Electric Type H, 25 cycle, oil insulated, self cooled, single phase transformers which are Y connected on both primary and secondary.

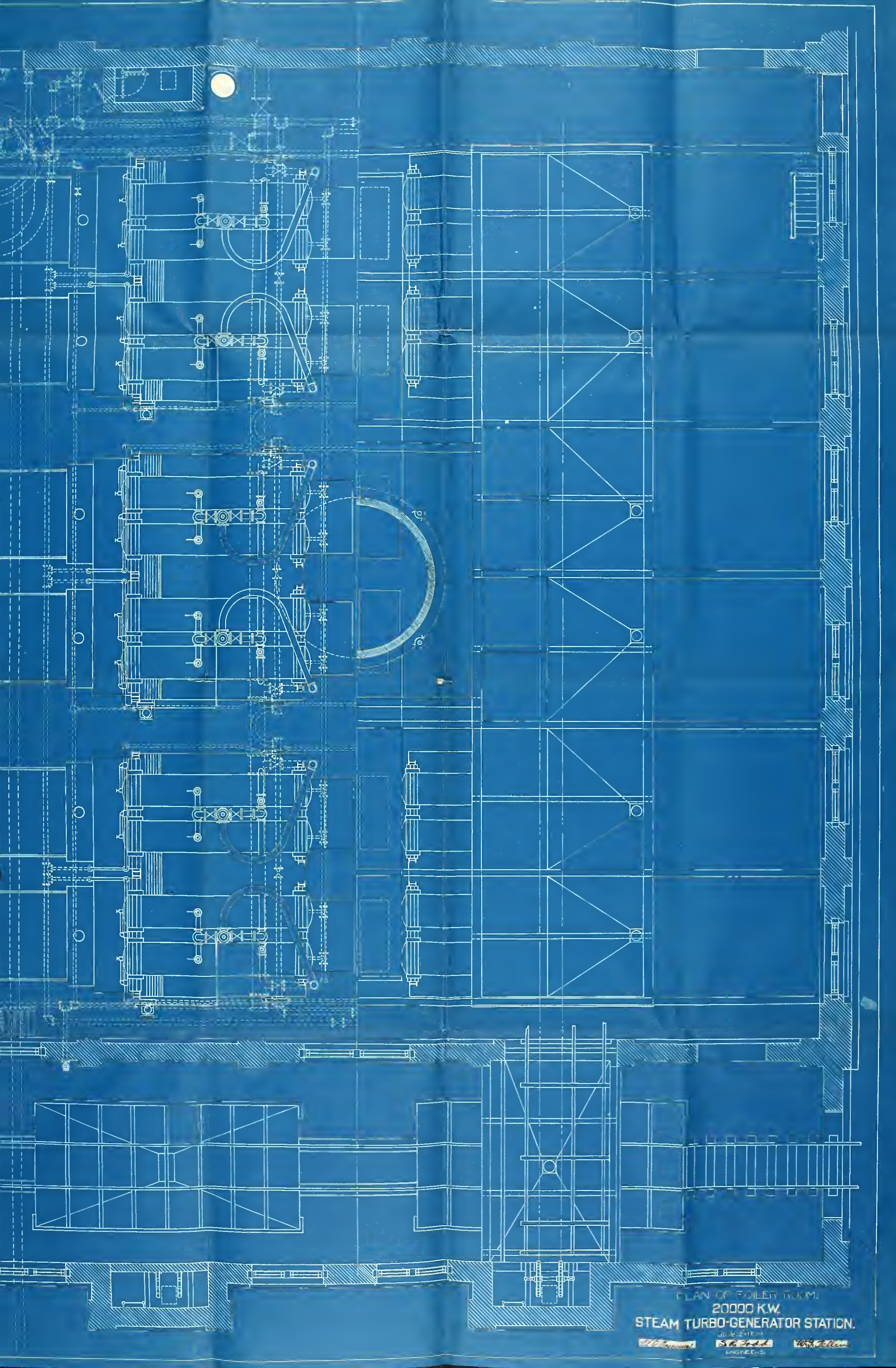
The three phase line comes in through disconnect switches and choke coils to a T.P.S.T.

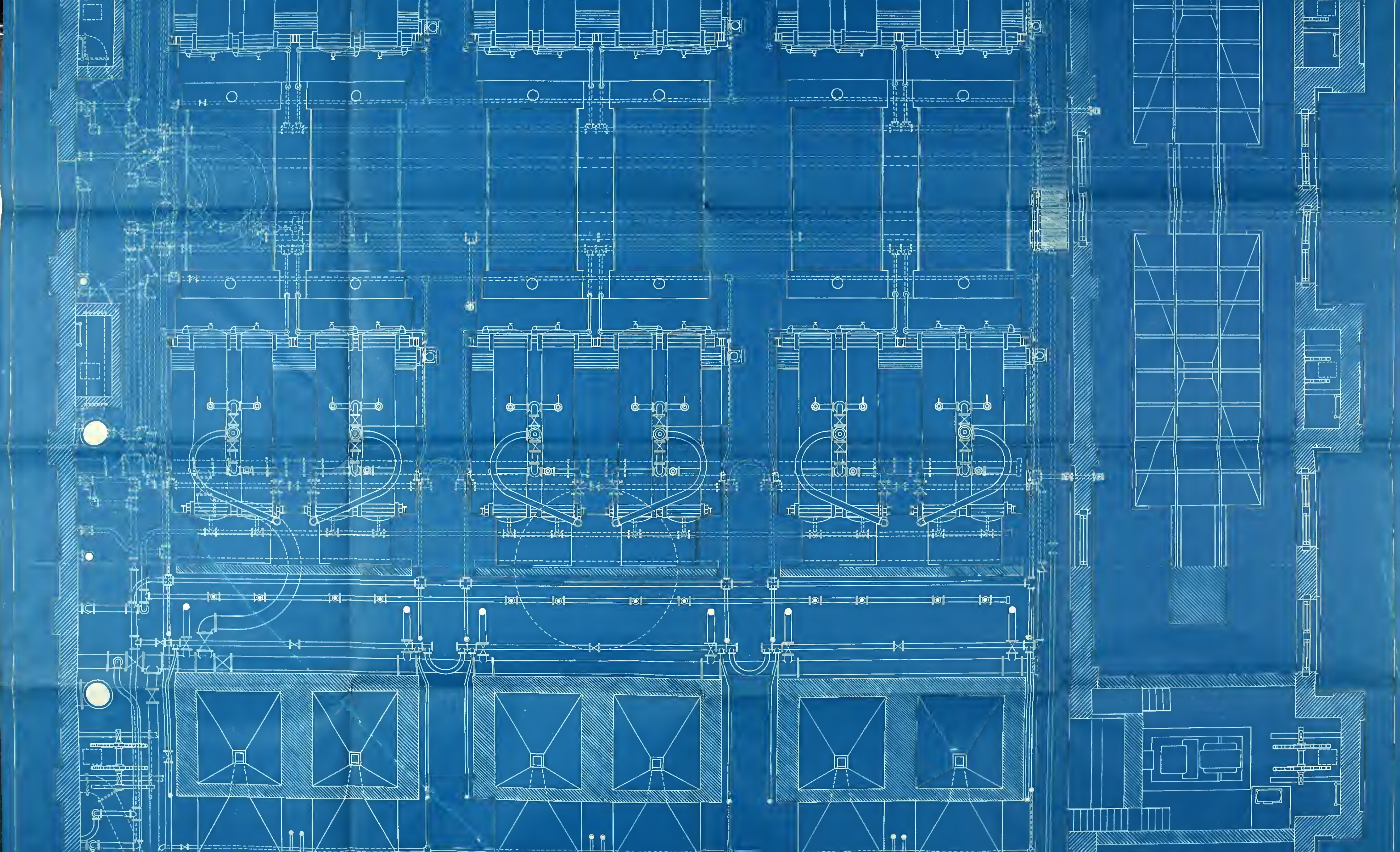
General Electric hand operated, automatic release oil switch the station side of which is directly connected to the transformers. On the main panel are mounted the oil switch, a volt- meter indicating the line voltage, and a poly-phase integrating wattmeter which measures the total power consumed in the sub-station.

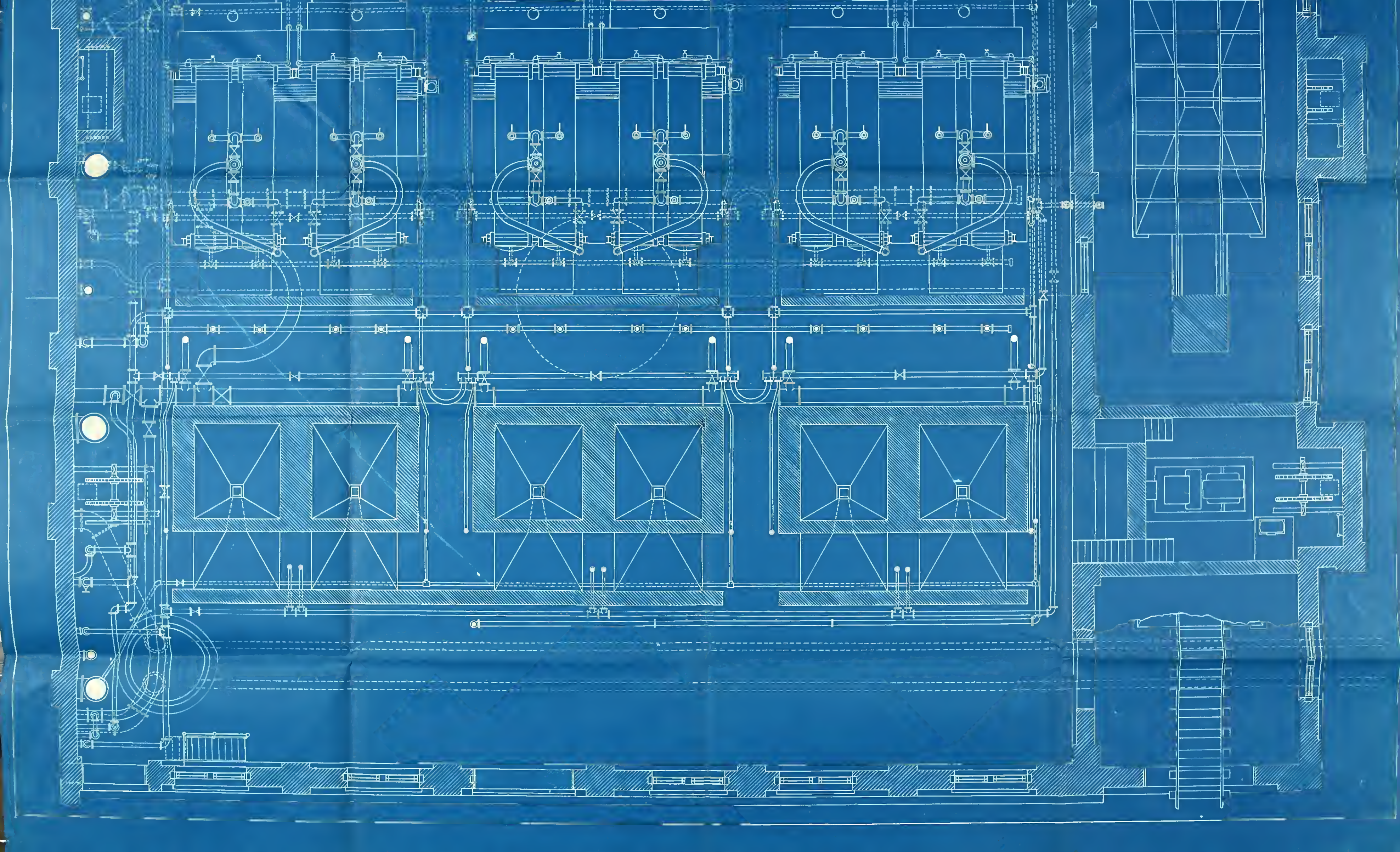
There are thirty arc circuits of fifty lights each, ten of which are connected in each phase thus insuring a balanced load. The circuit panels are all situated on a mezanine floor and have mounted on them a (0 to10) ammeter, a series transformer, and two 10,000-volt 15 amp. stab switches. The current for the arcs is kept constant by means of a G. E. 50- light impedance regulators,and main panel are also located on the mezanine floor. The design of the above described arc light sub-station was determined after careful study and investigation of the most modern sub-stations of this class.

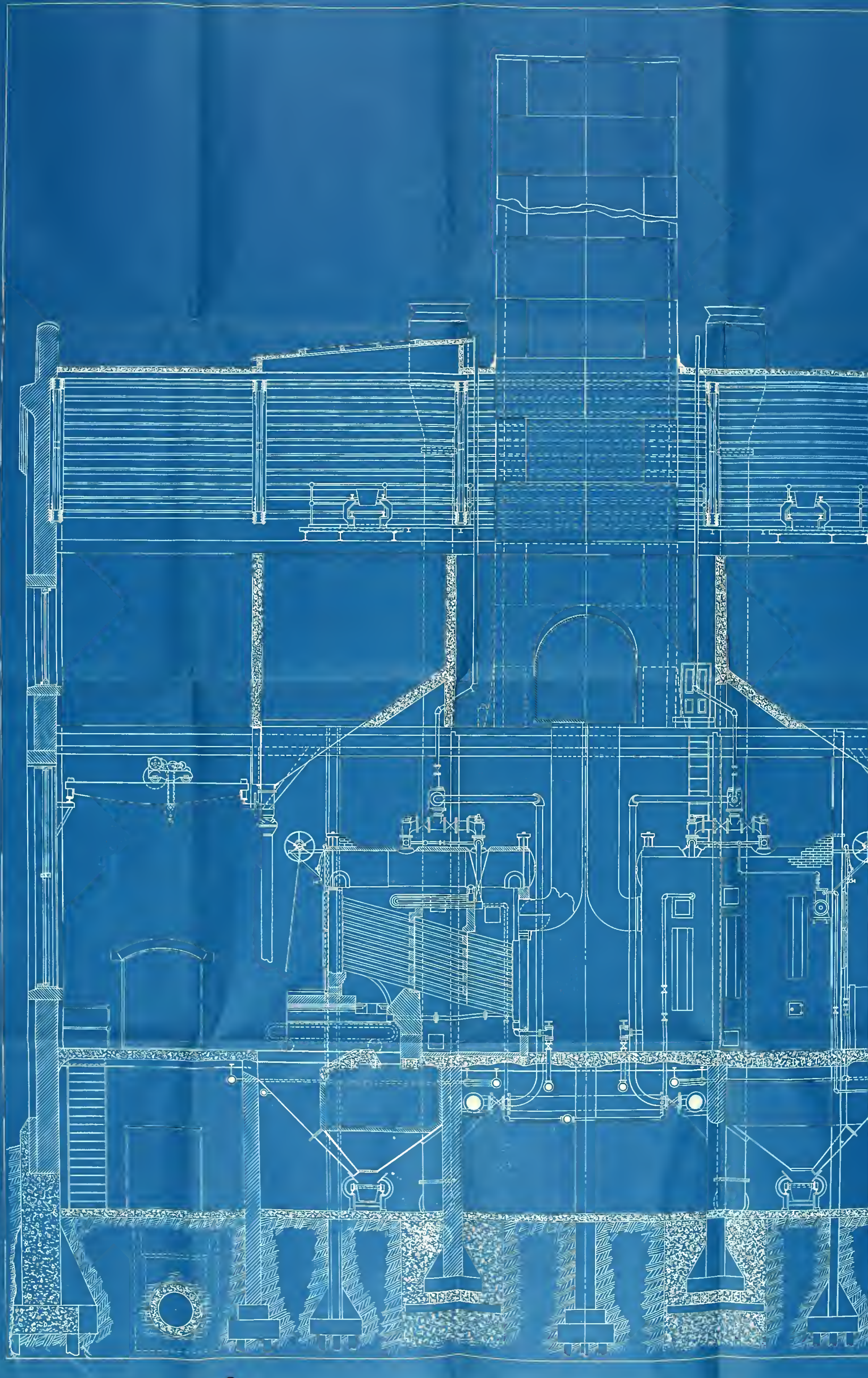


20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
K.W. Load.
Average Load Curve
Forenoon.
Afternoon.
12
2
4
6
8
10
12
2
4
6
8
10
12


PLAN OF BOILER ROOM.
20000 K.W.
STEAM TURBO-GENERATOR STATION.







CROSS-SECTION OF BOILER ROOM.

20000 K.W.
STEAM TURBO-GENERATOR STATION

[illegible]

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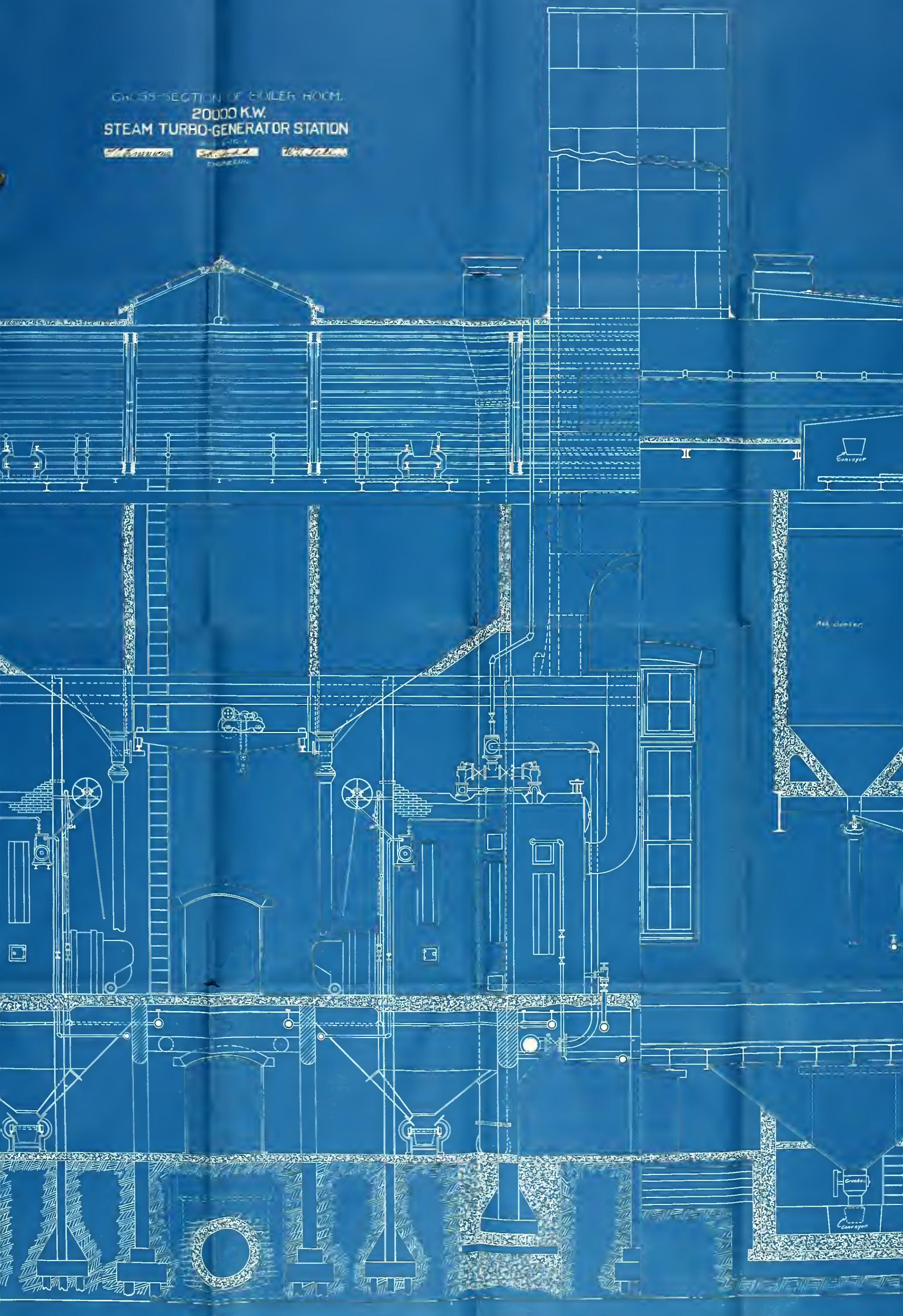
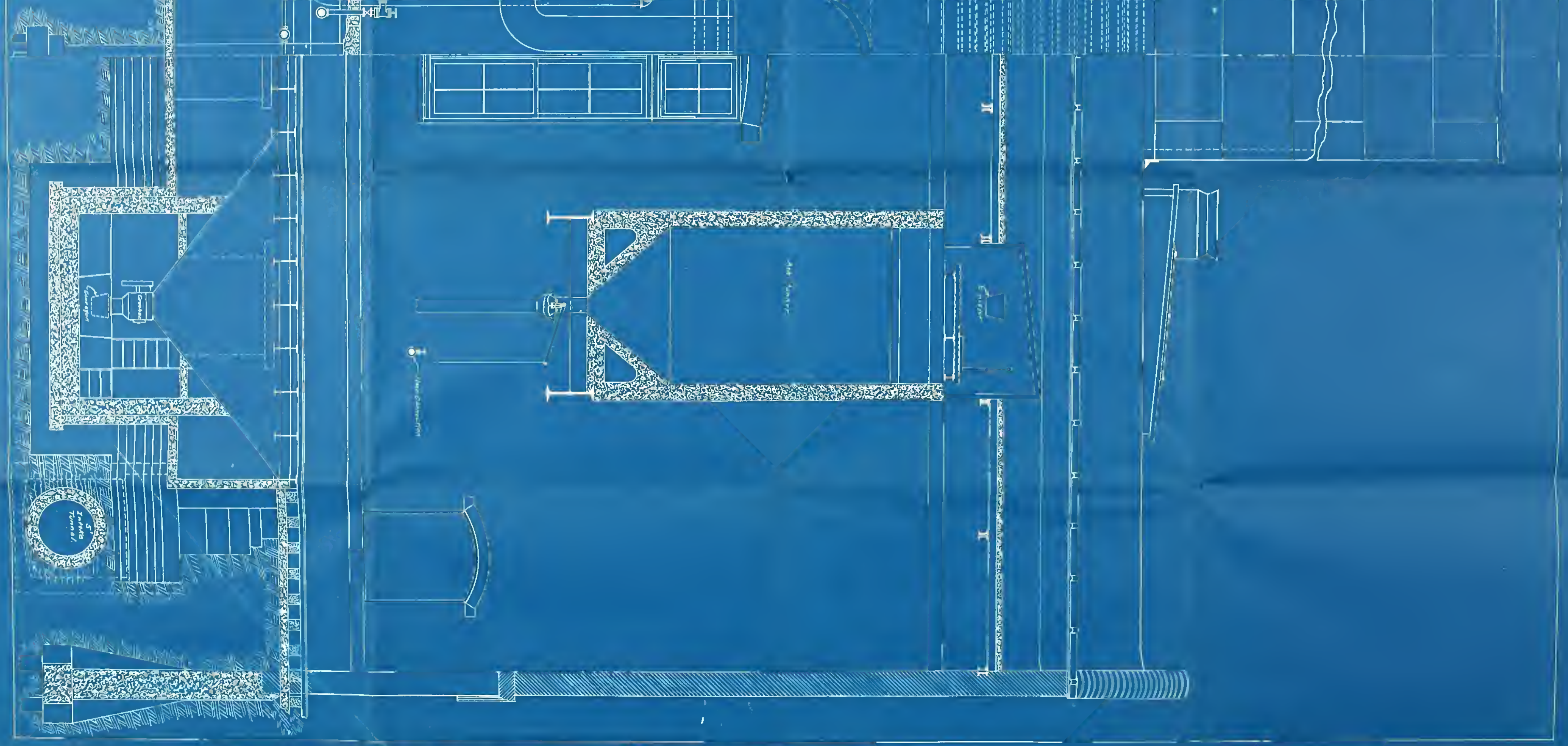
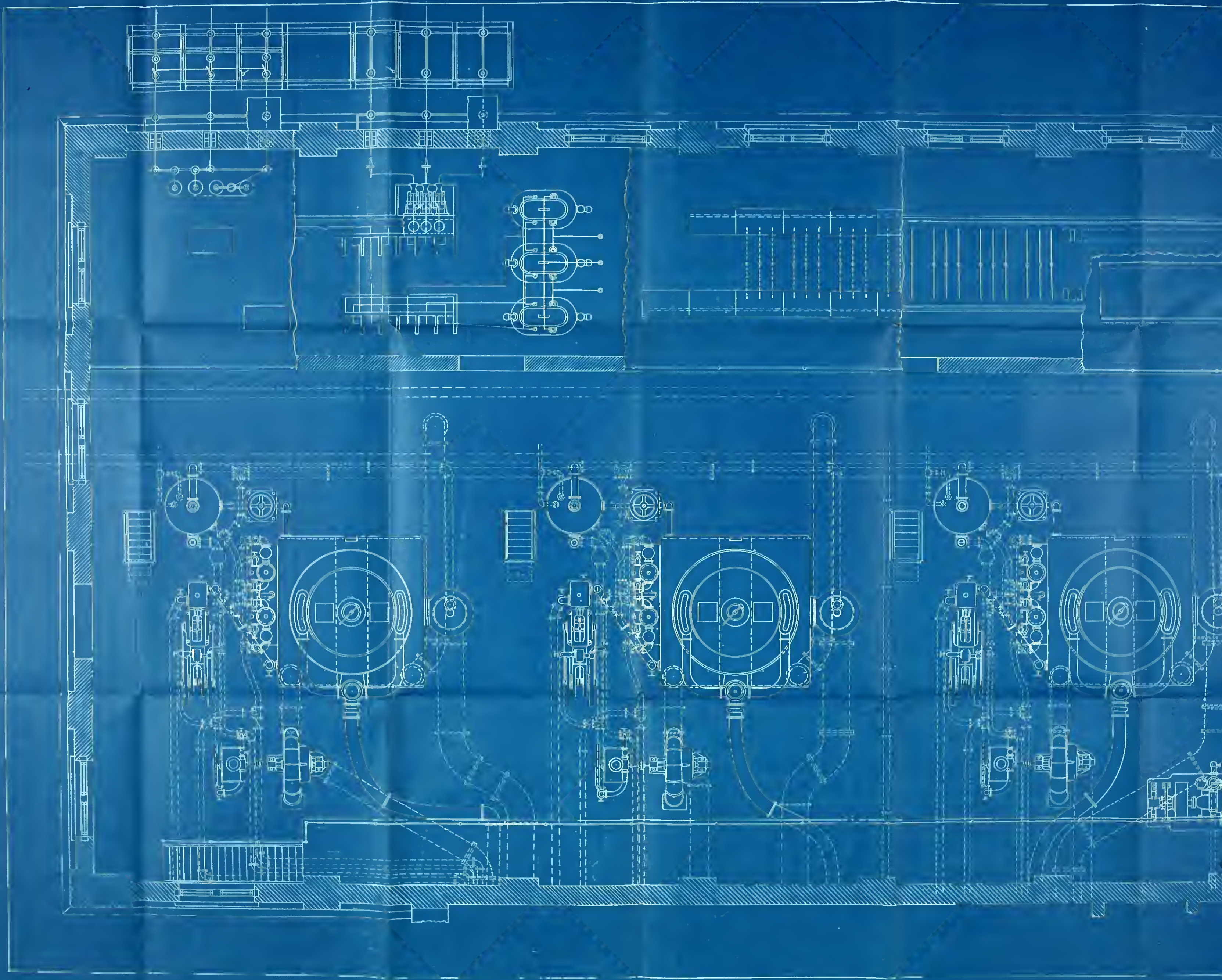
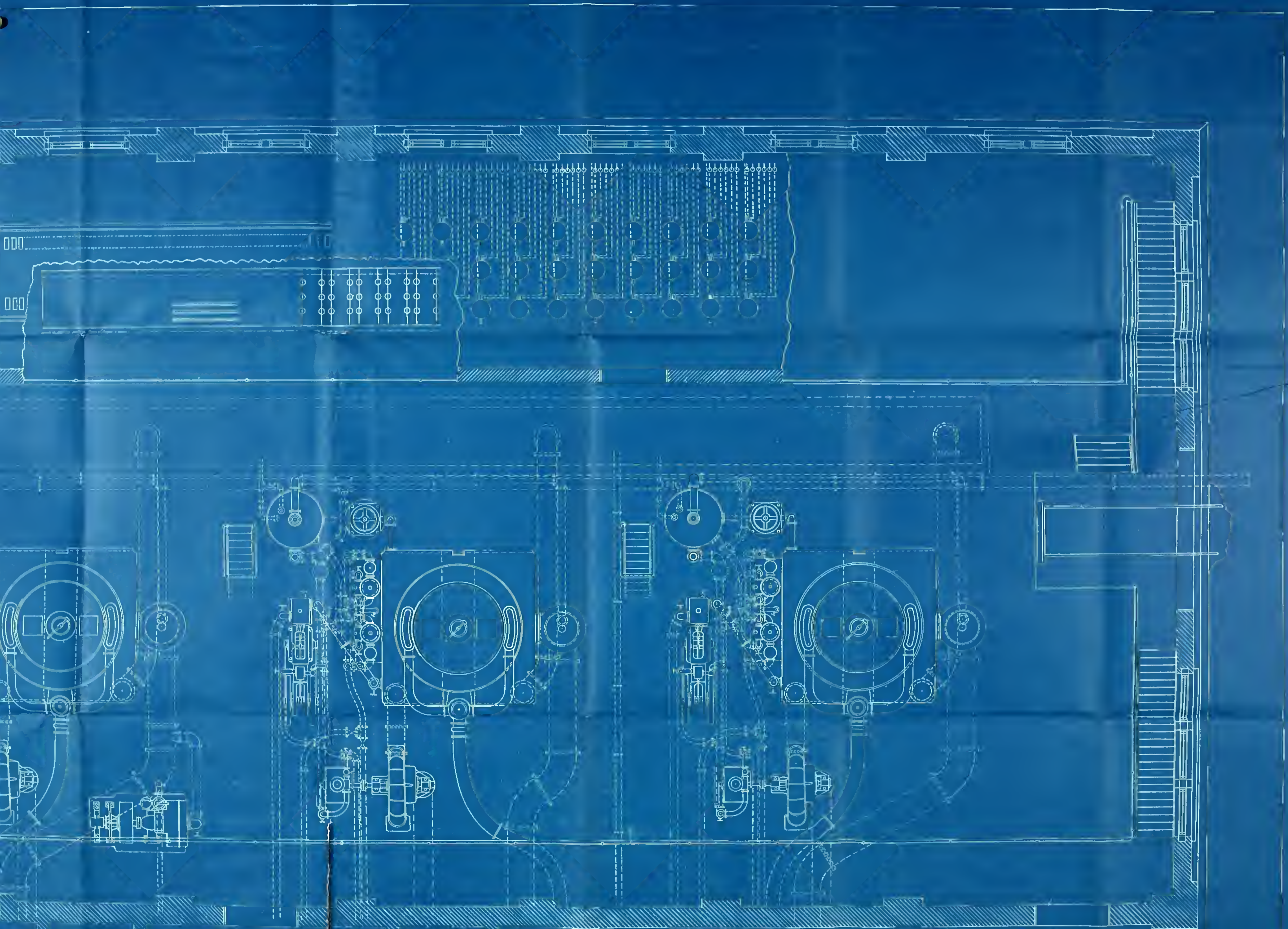



Conveyor
Crusher
Hose Connection
Ash Tunnel
5' Intake Tunnel.



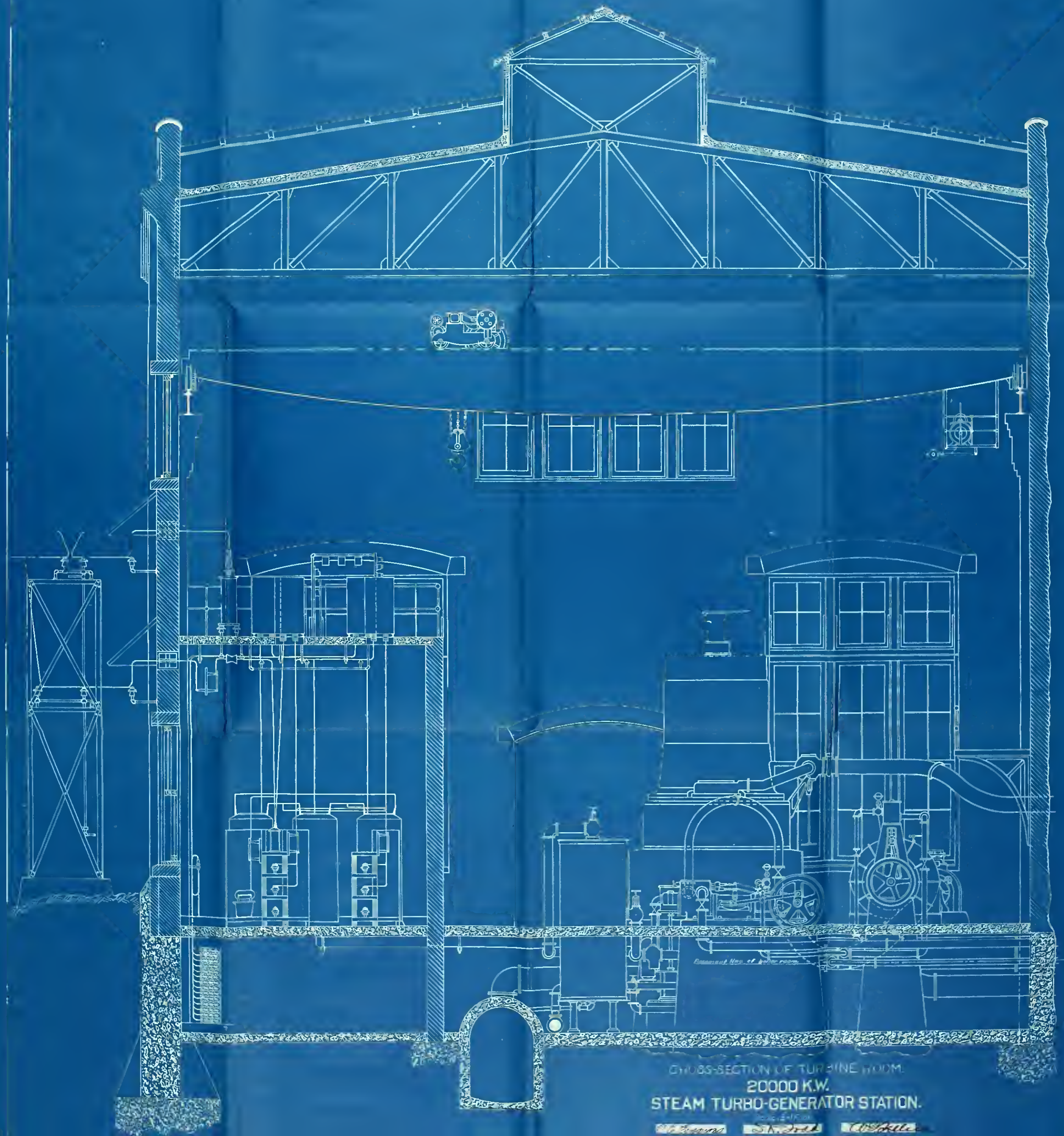


PLAN OF TURBINE ROOM
20000 K.W.
STEAM TURBO-GENERATOR STATION

Scale: ¼"=1 Foot.

Todd

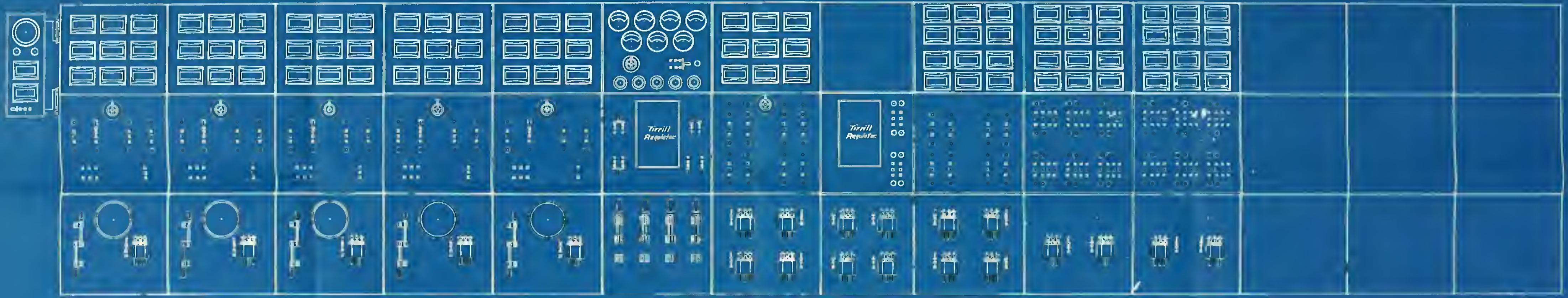
ENGINEERS.



CROSS-SECTION OF TURBINE ROOM.

20000 K.W.

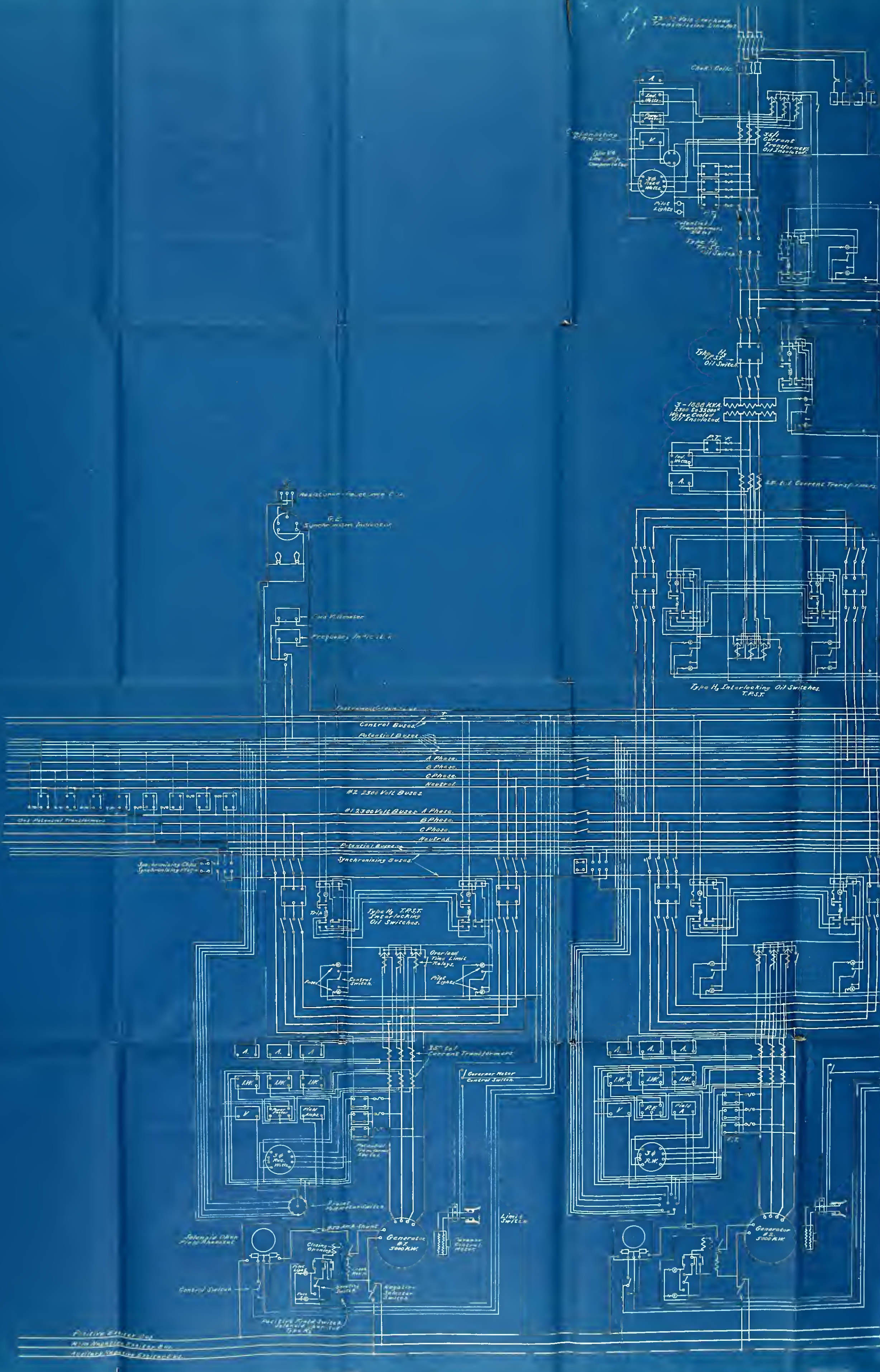
STEAM TURBO-GENERATOR STATION.

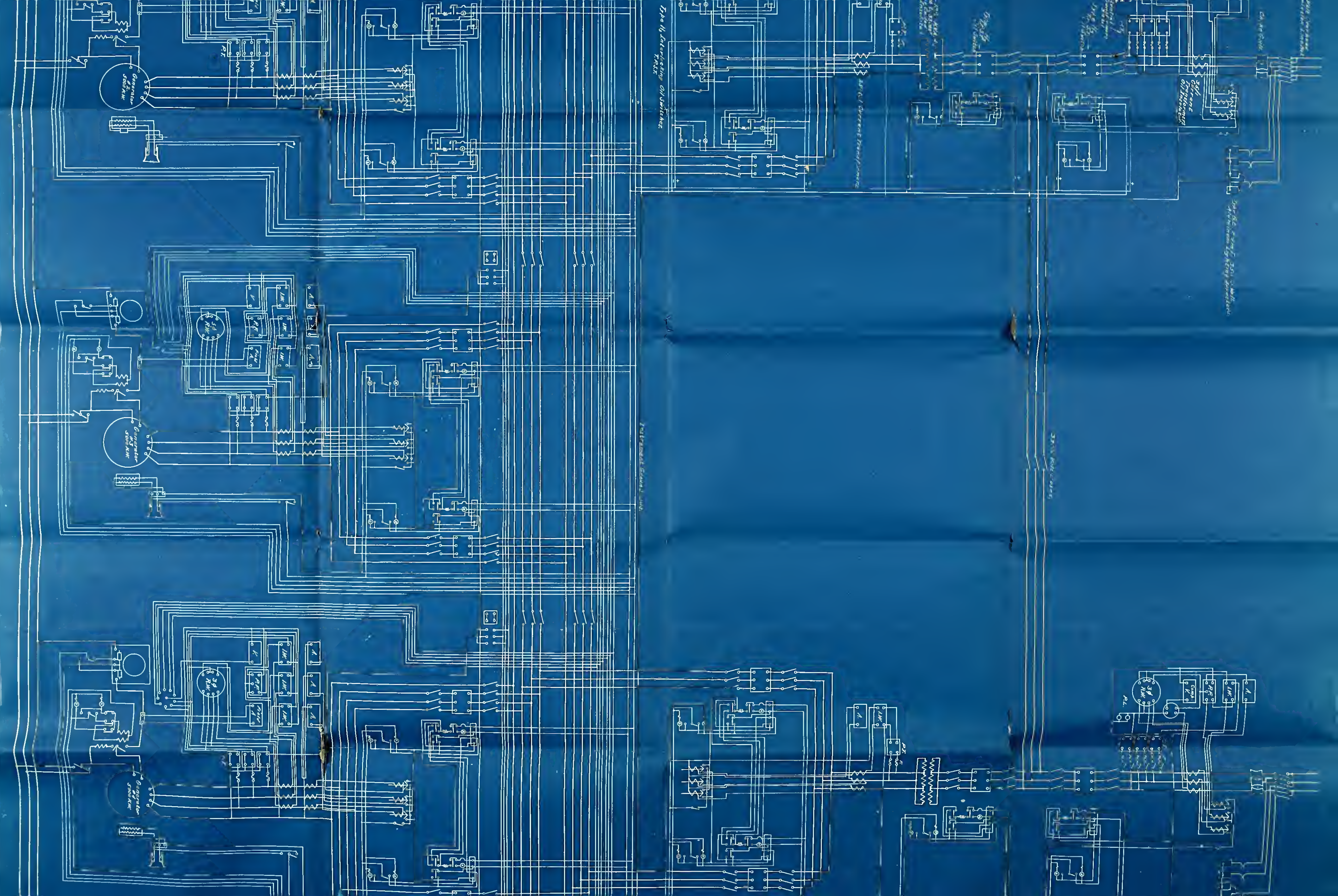


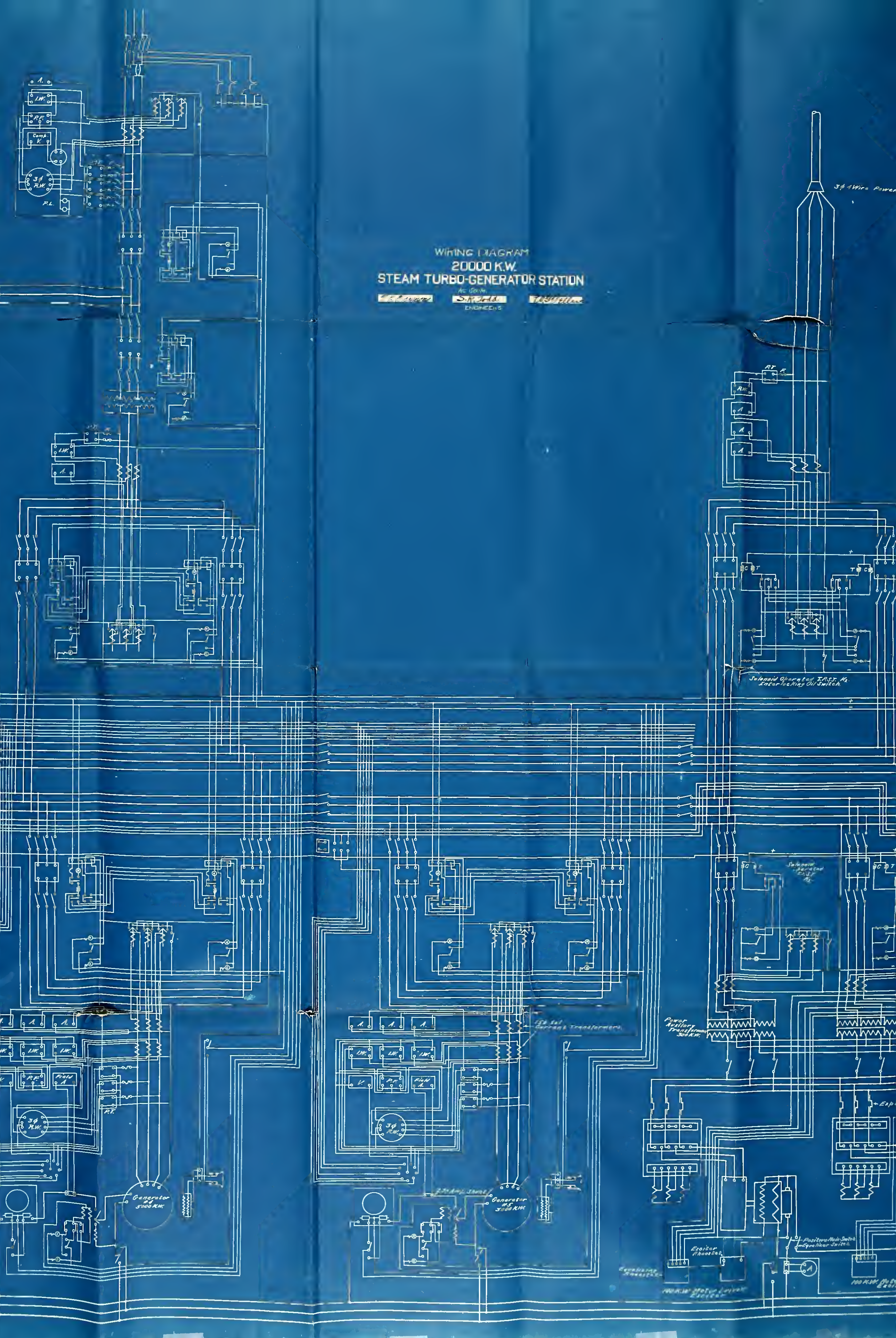
FRONT ELEVATION OF SWITCHBOARD
20000 K.W.
STEAM TURBO-GENERATOR STATION

Scale $\frac{3}{4}$"=1 Foot.

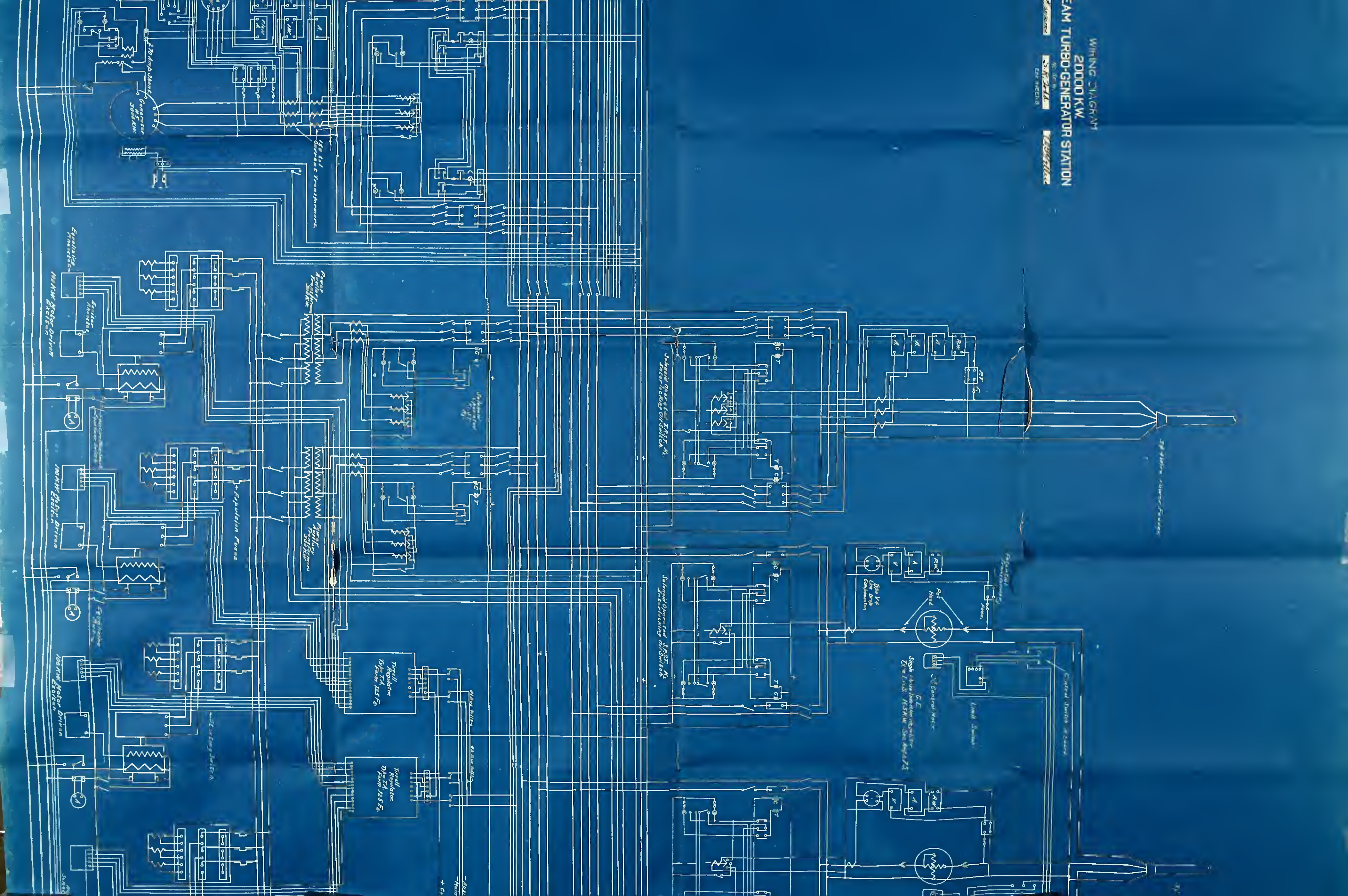
S. R. Todd
ENGINEERS.


33,000 Volt Overhead Transmission Line No.
Choke Coils
A
Ind. Watts
Power Factor
V
Line Drop Compensator
3ϕ Rec'd Watts
Pilot Lights
Potential Transformers
35/1 Current Transformers Oil Insulated.
Type H3 T.P.S.T. Oil Switch.
3 - 1666 K.V.A. 2300 to 35000 V Water Cooled Oil Insulated.
P.T. F.
Ind. Watts
A.
Current Transformers
Type H3 Interlocking Oil Switches. T.P.S.T.
G.E. Synchronism Indicator
Frequency Indicator
Control Buses.
Potential Buses.
A Phase.
B Phase.
C Phase.
Neutral.
#2 2300 Volt Buses.
#1 2300 Volt Buses. A Phase.
B Phase.
C Phase.
Neutral.
Potential Buses.
Synchronizing Buses.
Potential Transformers
Trip
Type H3 T.P.S.T. Interlocking Oil Switches.
Overload Time Limit Relays.
Fuses
Control Switch.
Pilot Lights.
A.
A.
A.
I.W.
I.W.
I.W.
V
Power Factor
Field Amps.
3ϕ Rec. Watts
Current Transformers
Governor Motor Control Switch.
Limit Switch
Generator #1 5000 K.W.
Closing
Opening
Pilot Light
Fuse
Control Switch
Positive Exciter Bus.
Main Negative Exciter Bus.
Auxiliary Negative Exciter Bus.
A.
A.
A.
I.W.
I.W.
I.W.
V
P.F.
Field A
3ϕ R.W.
Generator #2 5000 K.W.

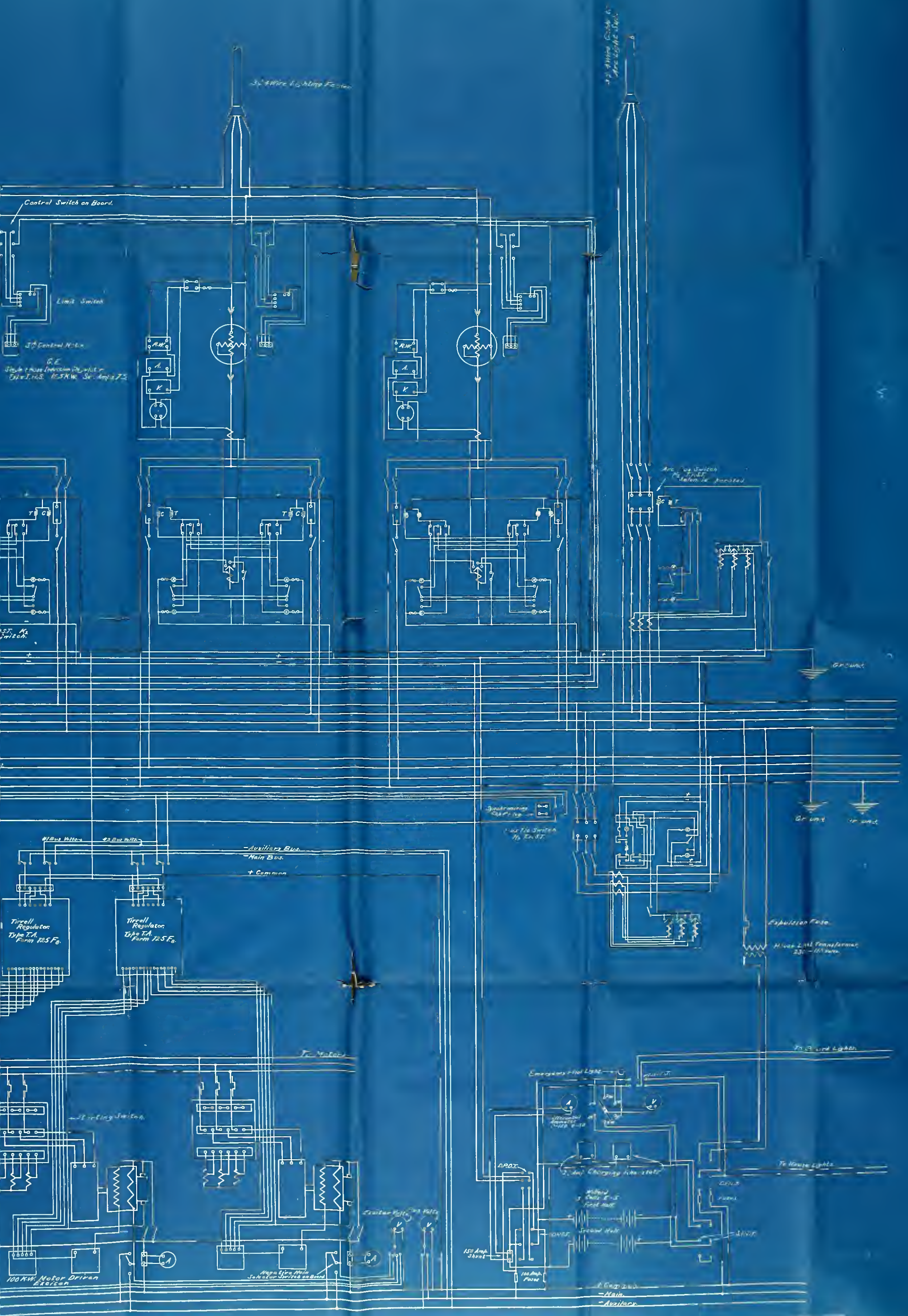

Generator
#3
500 KW
Type H Interlocking Oil Switches
T.P.S.T.
Current Transformers
35 ~1 Current Transformers Oil Insulated
Potential Ground Line
V
I.W.
P.F.
A
3 φ K.W.
P.T.
P.L.

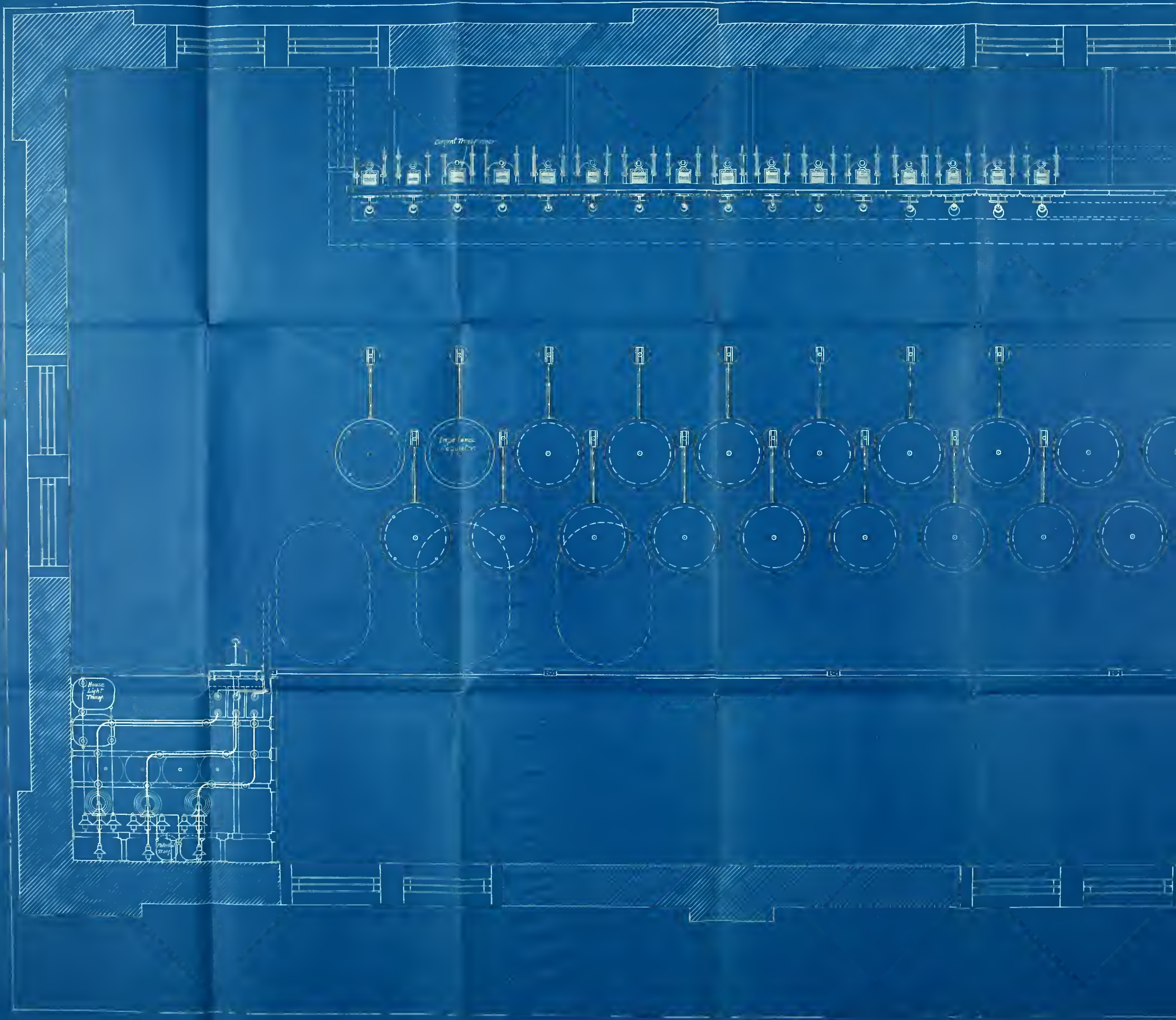


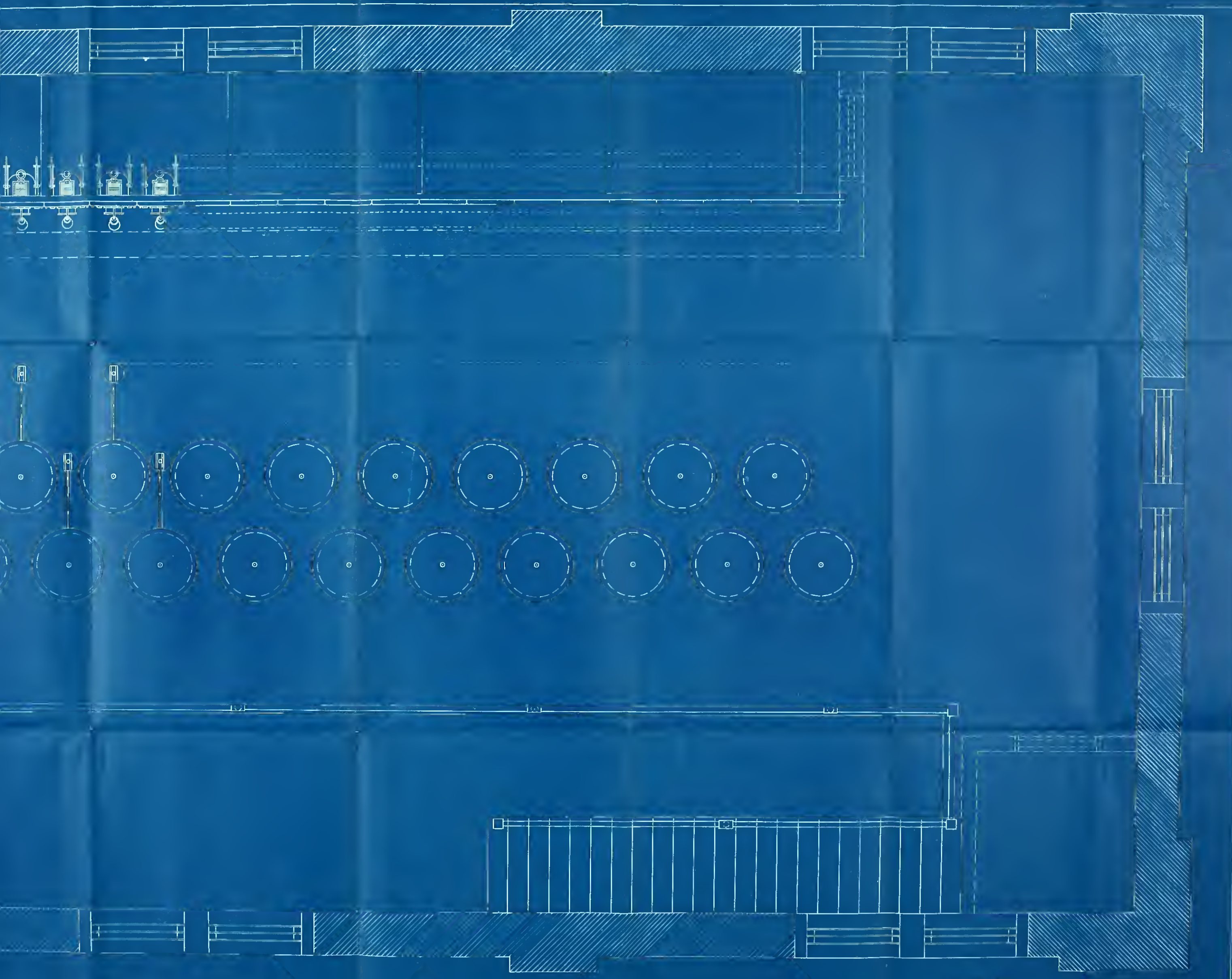
WIRING DIAGRAM
20000 K.W.
STEAM TURBO-GENERATOR STATION
No Scale
ENGINEERS


Generator 2000 K.W.
Current Transformers
Equalizing Rheostats
Exciter Rheostat
100 K.W. Motor Driven Exciter
Power Auxiliary Transformers
Expulsion Fuses
Solenoid Operated T.P.S.T. K4 Interlocking Oil Switch
Solenoid Operated S.P.S.T. K4 Interlocking Oil Switch
Tirrill Regulator Type T.A. Form 725 Fo.
Line Volt Drop Compensator
Pot. Head
Control Switch
To 6600 Volt Lines

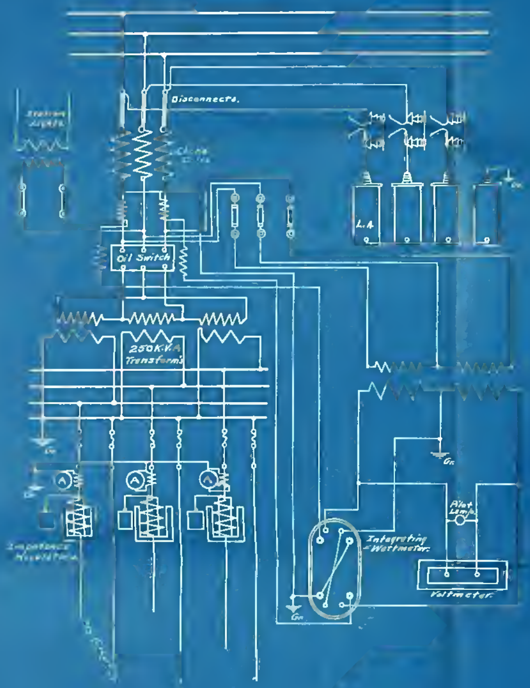
WIRING DIAGRAM
2000 K.W.
EAM TURBO-GENERATOR STATION

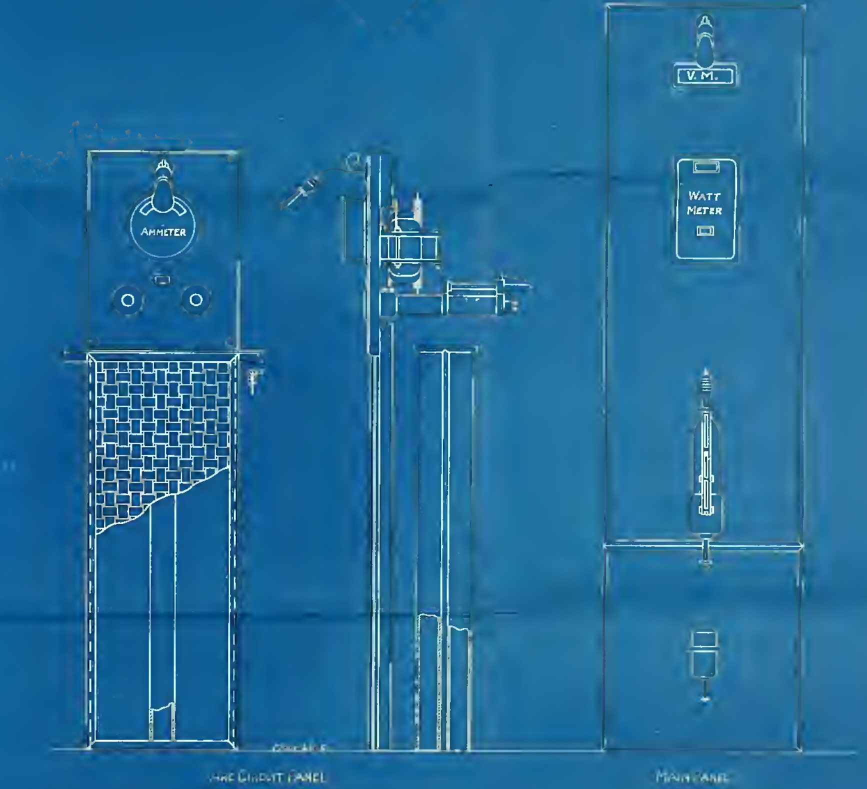

3φ 4 Wire Lighting Feeder
3φ 4 Wire Cable to Arc Light Sw.
Control Switch on Board.
Limit Switch
3φ Control Motor
G.E.
Single Phase Induction Regulator
Type I.R.S. 15.5 K.W. Sec. Amps 75
R.W.
A.
V.
Arc Sw. Switch
Solenoid Operated
T.P.S.T. M. Switch
Ground
Ground
Ground
Synchronizing Plug
Bus Tie Switch
Expulsion Fuse
House Light Transformer 230 - 110 Volts
#1 Bus Volts
#2 Bus Volts
- Auxiliary Bus.
- Main Bus.
+ Common
Tirrell Regulator Type T.A. Form 125 F8.
Tirrell Regulator Type T.A. Form 125 F8.
To Motors
Starting Switch
Exciter Volts
Gen Volts
100 K.W. Motor Driven Exciter
Negative Main Selector Switch on Board
To Ground Lights
Emergency Pilot Light
Differential Ammeter
To House Lights
D.P.D.T.
Charging Rheostat
Cells E-5 First Half
Second Half
150 Amp Shunt
100 Amp Fuses
Fuses
+ Common
- Main
- Auxiliary


Current Transformer
Impedance Regulator
House Light Transf.
Potential Transf.



PLAN OF
650 K.W. ARC LIGHT SUB-STATION
20000 K.W.
STEAM TURBO-GENERATOR STATION
Scale: $\frac{1}{4}$"=1 Foot.
S. R. Ladd
ENGINEER

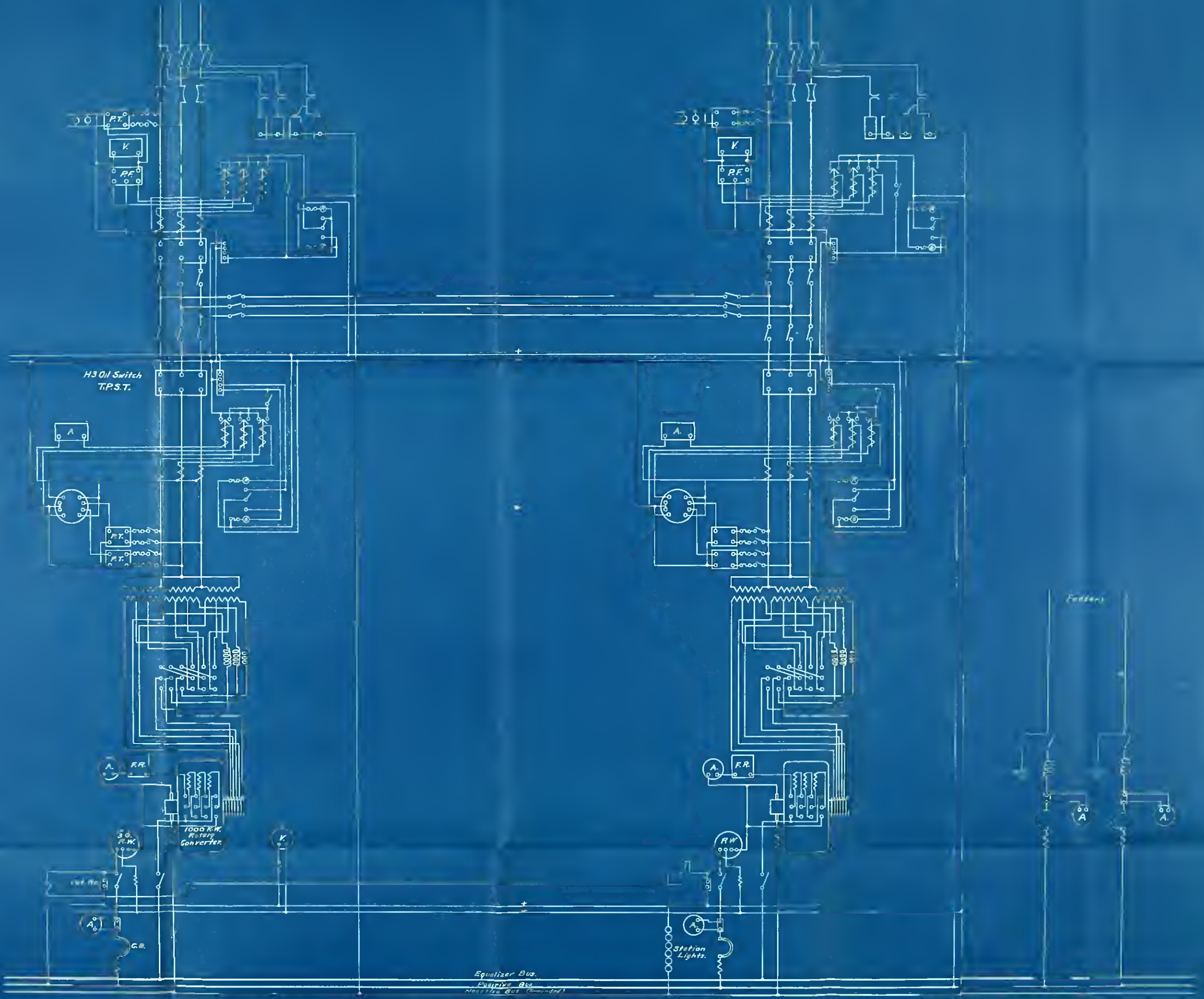




WIRING DIAGRAM AND PANEL ELEVATIONS
650 K.W. ARC LIGHT SUB-STATION
20000 K.W.
STEAM TURBO-GENERATOR STATION

J. R. Todd

ENGINEERS.



SUB-STATION WIRING DIAGRAM

20000 K.W.

STEAM TURBO-GENERATOR STATION.

De[illegible]

S.R.

ENGINEERS.